Critical Earth Observation Priorities

GEO Task US-09-01a

Air Quality and Health

Report to the GEO User Interface Committee

Prepared by
Rudolf B. Husar, Analyst
Washington University in St. Louis
Stefan R. Falke, Co-Analyst
Washington University in St. Louis, Northrop Grumman Corp

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DRAFT

Group on Earth Observations

GEO Task US09-01a:
Earth Observation Priorities for Air Quality and Health SBA

Advisory Group Members & Analyst

The following people served as expert panelists for the *ad hoc* Advisory Group for the Air Quality and Health Societal Benefit Area under GEO Task US-09-01a. The Advisory Group supported the Analyst by identifying source materials, reviewing analytic methodologies, assessing findings, and reviewing this report.

Jeff BROOKS, Env. Canada
Jack FISHMAN, NASA Langley
Barry JESSIMAN, Health Canada
Patrick KINNEY, Columbia University
Jim MEAGHER, NOAA
Rashmi S. PATIL, IIT Bombay
Leonora ROJAS, National Institute of Ecology
Paulo SALDIVA, University of São Paulo
Rich SCHEFFE, EPA OAR/OAQPS
Kjetil TORSETH, Norwegian Institute of Air Research
Michael GATARI, Univ. of Nairobi

The following person/people served as the Analyst for the Air Quality and Health Societal Benefit Area under GEO Task US-09-01a, providing overall coordination of the analysis and preparation of this report.

Rudolf HUSAR, Washington University, Principal Analyst
Stefan FALKE, Washington University/Northrop Grumman, Co-Analyst

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Group on Earth Observations

GEO Task US09-01a:
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The summary should provide a very brief overview of the major elements of the report. Here's a suggested list of topics to cover in 1-2 sentences each.

- *General statement about Task US-09-01a*
- *SBA focus of this report, including sub-areas focused on*
- *# of advisory group members and geographic distribution*
- *# of documents, including the methods used to identify and select them*
- *Analytic methods to analyze the documents and select observations for each sub-area*
- *General statements about observations for each sub-area (e.g., # for each sub-area)*
- *Methods used to prioritize the observations to establish a prioritized set for the SBA*
- *Priority observations (if too many to list, then have a statement about them, a statement about general categories, and/or a reference to the section in the document)*
- *Any major conclusions and recommendations*

This meta-analysis indicates that the per-capita AQ monitoring in the developing regions of the world is 10-20 times lower than in the developed N. America and Western Europe, the monitoring of PM2.5, the best available indicator of health-related effects is virtually un-monitored in the developing world and the existing monitoring data from developing regions is also less publicly accessible to the broader health community. Consequently, there is a need for significantly extended AQ monitoring in the developing world, particularly in the large, densely populated cities, more intense monitoring and managing the concentration of PM2.5 and improving the accessibility to AQ monitoring data by the broader communities in science, AQ management and the general public.

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GEO Task US09-01a:
Earth Observation Priorities for Air Quality and Health SBA

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GEO Task US-09-01a: Earth Observation Priorities for Air Quality and Health SBA

1. Introduction

This report articulates Earth observation priorities for the Human Health: Air Quality SBA based on an analysis of 100+ publicly-available documents, including documents produced by Group on Earth Observations (GEO) member countries and participating organization.

1.1 Group on Earth Observations

The Group on Earth Observations (GEO, www.earthobservations.org) is an intergovernmental organization working to improve the availability, access, and use of Earth observations to benefit society. GEO is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS) . GEOSS builds on national, regional, and international observation systems to provide coordinated Earth observations from thousands of ground, airborne, and space-based instruments.

GEO is focused on enhancing the development and use of Earth observations in nine Societal Benefit Areas (SBA): Agriculture, Biodiversity, Climate, Disasters, Ecosystems, Energy, Human Health, Water, Weather.

1.2 GEO Task US-09-01a

The objective of GEO Task US-09-01a is to establish and conduct a process to identify critical Earth observation priorities within each Societal Benefit Area (SBA) and those common to the nine SBAs. Many countries and organizations have written reports, held workshops, sponsored projects, conducted surveys, and produced documents that specify Earth observation needs. In addition, researchers and practitioners have also identified and recommended key Earth observation needs in publications and peer-reviewed literature. Task US-09-01a focuses on compiling information on observation parameters from a representative sampling of these existing materials and conducting analyses across the materials to determine priority observations.

1.3 Purpose of Report

The primary purpose of this report is to articulate the critical Earth observation priorities for the Human Health SBA, specifically for Air Quality and Health (AQH) as

it affects human health and well-being. The Human Health SBA EO priorities are addressed by two additional reports within GEO Task US-0901a: Infections Diseases and Aeroallergens. The intent of this report is to describe the overall process and specific methodologies used to identify documents, analyze them, and to determine a set of Earth observation parameters and characteristics. The report describes the prioritization methodologies used to determine the priority Earth observations for this SBA. The report also provides information on key challenges faced, feedback on the process, and recommendations for process improvements.

The primary audience for this report is the GEO User Interface Committee (UIC), which is managing Task US-09-01a for GEO. The GEO UIC will use the results of this report in combination with reports from the other eight SBAs. The GEO UIC will perform a meta-analysis across all nine SBA reports to identify critical Earth observation priorities common to many of the SBAs. Based on the nine SBA reports, the GEO UIC will produce an overall Task US-09-01a report, including the common observations and recommendations for GEO processes to determine Earth observation priorities in the future. The report's authors anticipate that the GEO Secretariat, Committees, Member Countries, Participating Organizations, Observers, Communities of Practice, and the broader communities associated with the Human Health and other SBAs are additional audiences for this report.

1.4 Scope of Report

This report addresses the Earth observation priorities for the Human Health SBA. In particular, this report focuses on the sub-area of Air Quality within the Human Health SBA (see Section 3 for more details). The report provides some background and contextual information about AQH. However, this report is not intended as a handbook or primer on AQH, and a complete description of the AQH is beyond the scope of this report. Please consult the GEO website (http://www.earthobservations.org) for more information about the Human Health SBA and its sub-areas.

The report focuses on the Earth observations for Air Quality and Health, independent of any specific technology or collection method. Thus, the report addresses the "demand" side of observation needs and priorities. It does not address the specific source of the observations or the sensor technology involved with producing the observations. Similarly, any discussions of visualization tools, decision support tools, or system processing characteristics (e.g., data format, data outlet) associated with the direct use of the observations are beyond the scope of this report.

The term Earth observation (EO) refers to parameters and variables (e.g., physical, geophysical, chemical, biological) sensed or measured, derived parameters and products, and related parameters from model outputs. The term Earth observation priorities refers to the parameters deemed of higher significance than others for the given SBA, as determined through the methodologies described within. The report uses the terms "user needs" and "user requirements" interchangeably to refer to Earth observations that are articulated and desired by the groups and users in the

cited documents. The term “requirements” is used generally in the report to reflect users’ wants and needs and does not imply technical, engineering specifications.

Following this introduction, the report discusses the overall approach and methodologies used in this analysis (Section 2). Section 3 describes the Air Quality and Human Health SBA and the specific sub-areas. Section 4 articulates the specific Earth observations on Air Quality for Human Health and well-being. Section 5 presents the priority observations for Air Quality and Health. Sections 6 and 7 present additional findings from the analysis of the documents and any recommendations. The Appendices include the documents cited as well as additional information describing aspects of Air Quality and Human Health and Welfare.

2. Methodology and Process

This section documents the general process followed and describes the specific methodologies used to identify documents, analyze them, determine Earth observation parameters and characteristics, and establish a set of priority Earth observations for this SBA. It (1) outlines the general task process approach, (2) identifies the analyst and the advisory group and (3) describes the methodologies used for this meta-analysis, which consist of (a) document selection, (b) an approach for defining and extracting AQ EO needs and (c) analytical methods for prioritizing Earth Observations for AQ.

2.1 Task Process

The GEO UIC established a general, but uniform, process that is to be applied by each of the SBAs. The intent is to ensure a level of consistency across the SBAs. This general process for each SBA involves nine steps, as summarized in the following list:

- Step 1: Identify Analyst and Advisory Group for the SBA
- Step 2: Determine scope of topics within the SBA
- Step 3: Identify documents regarding observation priorities for the SBA
- Step 4: Develop analytic methods and priority-setting criteria
- Step 5: Review and analyze documents for priority Earth observations needs
- Step 6: Combine the information and develop a preliminary report
- Step 7: Gather feedback on the preliminary report
- Step 8: Perform any additional analysis
- Step 9: Complete the report on Earth observations for the SBA

A detailed description of the general US-09-01a process is available at the Task website, http://sbageotask.larc.nasa.gov, or the GEO website. Some steps in the process occurred simultaneously or iteratively, such as identifying documents (Step 3), reviewing documents (Step 5) and developing priority methodology (Step 4).

2.2 Analyst and Advisory Group

The Health and Air Quality group included an “Analyst” and an “Advisory Group” to conduct the process of identifying documents, analyzing them, and prioritizing the Earth observations. The Analyst served as the main coordinator to manage the activities.

2.2.1 Analyst

The Analyst for this Air Quality and Health EO Requirement Report was Dr. Rudolf Husar (lead analyst) and Dr. Stefan Falke (co-analyst). Rudolf Husar is a Professor of Energy, Environmental and Chemical Engineering and director of the Center for Air Pollution Impact and Trend Analysis (CAPITA) at Washingon University in St. Louis, MO. Over the past 35 years Husar conducted parallel research in air pollution (sources, transport, transformations, effects) and in environmental informatics. Husar has served on committees of NAS, EPA CASAC as well as international advisory groups, including WMO, IGAC. Recently Husar's research group has actively participated in various aspects of the evolving GEOSS, including the GEOSS Common infrastructure (GCI), the Architecture Implementation Pilot (AIP), and the GEOSS Air Quality Community of Practice (CoP). Stefan Falke is a Research Assistant Professor of Energy, Environmental and Chemical Engineering at Washington University in St. Louis and Manager of Geospatial Information Services for Energy and Environment at Northrop Grumman. Stefan serves as co-chair, with Rudolf Husar, of the Earth Science Information Partners Federation (ESIP) Air Quality Workgroup, which fosters interaction among satellite, aerial, surface, and modelled data producers, brokers, and consumers, and that is setting the foundation for an international GEOSS Air Quality Community of Practice. He has also recently been appointed to lead the Atmospheric Science Interest Group within the Working Group on Information Systems & Services (WGISS) in the Committee on Earth Observation Satellites (CEOS) with an initial focus on interoperability in access, tools, and contextual guidance for using remotely sensed atmospheric composition information across multiple countries.

In performing the document collection, analysis and preparation of this report, Husar and Falke were supported by Ph.D. student, Erin Robinson and Dr. Janja Husar. Collectively, they are referred to as the Analyst. The Analyst prepared this report with funding from EPA, though a subcontract from ERG, Jan Connery, Project Officer.

2.2.2 Advisory Group

The first step in the nine-step GEO Task US-09-01a process is the formation of an expert Advisory Group (AG) that helps identify appropriate documents, provides feedback on the analysis approach and also reviews the preliminary and final reports. For AQH, 18 potential AG members were identified. The sources of AG candidate names came from the UIC, major Agency representatives and the Analyst

team. Additional AG candidates were suggested by the AG members themselves. Eleven of the invited candidates responded favourably, two invitations were declined, five candidates did not respond. Effort was made to include representatives from developing nations and to achieve a representation across geographic domains. Additional AG members would be desirable, particularly from the developing countries.

The current Advisory Group consists of 11 experts from the field of Health and Air Quality or some subset thereof. Table 1 shows the Advisory Group members, including: Name, GEO Member Country or Participating Organization, Organizational Affiliation, Geographic Region, Specialty/Area of Expertise. Overall, the Advisory Group includes members from 7 countries and 5 continents, including 3 from developing countries. Five AG members have parallel expertise in air quality as well as human health.

Table 1: Advisory Group Members

Name	GEO Country or Organization	Affiliation	Region	Specialty
Jeff Brooks	Canada	Env. Canada	N. America	Air Quality
Jack Fishman	US	NASA Langley	N. America	Air Quality
Barry Jessiman	Canada	Health Canada	N. America	AQ and Health
Patrick Kinney	US	Columbia University	N. America	AQ and Health
Jim Meagher	US	NOAA	N. America	Air Quality
Rashmi S. Patil	India	IIT Bombay	Asia	AQ and Health
Leonora Rojas	Mexico	National Institute of Ecology	N. America	AQ and Health
Paulo Saldiva	Brazil	University of São Paulo	S. America	AQ and Health
Rich Scheffe	US	EPA OAR/OAQPS	N. America	Air Quality
Kjetil Tørseth	Norway	Norwegian Institute of Air Research	Europe	Air Quality
Michael Gatari	Kenya	University of Nairobi	Africa	Air Quality

The primary roles of the AG were to assist in identifying documents, assess methodologies and analytic techniques, assess prioritization schemes, review findings, and review the project report. The primary forms of communication with the AG were email and through the interactive open project wiki page. This report was prepared using an interactive wiki page on the Earth Science Information Partners (ESIP) server[1]. The members of the Analyst group used the wiki to collaboratively create the content, perform the editing and share the evolving report with the Advisory Group. The open wiki approach also provided a platform for sharing the document as it evolved and for receiving feedback both from the AG and the GEO Air Quality Community of Practice (ESIP Air Quality Work Group). The wiki, being a "living" and participating document, is available for future expansion or revisions, beyond the limited period of this initial GEO task (November 2009).

1. http://wiki.esipfed.org/index.php/GEO_User_Requirements_for_Air_Quality

2.3 Methodology

This section is a summary of analytic methods and approaches the Analyst used to identify documents, analyze them, and to establish a set of priority Earth observations. Since no standard approaches are available for establishing EO requirements and priorities applicable to all SBAs, the GEO Task Leader, Lawrence Friedl, has encouraged the Analysts of each SBA to be innovative and to consider multiple approaches toward developing their respective methodologies. However, strong emphasis was placed on the need to describe and document the chosen methodologies.

In the context of AQH, EOs refers to measurements or models that help characterizing the air quality and health systems, specifically emissions, source-receptor relationship, and ambient concentrations as described in section 3.1.

2.3.1 Document Selection

This section provides a general description of the process/method/approach the Analyst/AG used to identify documents and select a representative sampling for the analysis. Task US-09-01a methodology recommended the examination of a wide range of publicly available, geographically distributed sources for potentially relevant documents, including: International, regional, and national documents, project reports, surveys, workshop and conference summaries and peer-reviewed journal articles.

The candidate documents were identified using several methods: documents that were known to the Analyst; documents recommended by the Advisory Group and documents retrieved through online searches. The documents from the Analyst's prior knowledge (6) were based on decades of experience in AQ data analysis, network assessment and decision support for AQ management. The documents provided by the AG (11) contributed a broad range of perspectives as well as geographic coverage and contributions from developing countries. Key documents were also identified by back tracing from other documents. The online web searches contributed most of the documents (over 50) used in this report. The search focused on websites of international, regional, and national organizations engaged in Air Quality and Health. The general search also included published articles through Google Scholar using a combination of keywords, such as 'air pollution', 'health', and 'Africa'. The above selection process for qualified documents relies heavily on expert judgment and is inherently subjective.

Effort was made to select documents that contain specific statements on the EO requirements and also documents that discuss EOs for AQH. Documents that contain complete and directly applicable information on the above were found to be rare, mainly from consensus reports and workshop summaries. Documents that contained information on data quality were also rare. Public documents that identify specific EO priorities were most sparse as discussed in section 4.3.

Documents that are considered of special significance are cited in this report and also listed in Appendix B1: Documents and References Cited. The remaining documents consulted for the meta-analysis and bibliometric analysis are listed in Appendix B2: Documents and References Consulted.

2.3.2 Analytic Methods for Gathering EO Requirements

The analytic framework for AQH user requirements is science-based utilizing a systems approach to the analysis. The categories of observations are based on the AQ system components (see Section 3). The specific system components addressed in this analysis were: emissions, source-receptor relationship, and ambient concentrations. Both the method of gathering the user requirements as well as the prioritization is based on this AQ system framework.

The EO Requirements methodology development began with guidance provided by the Task leader, in the form of a standard table for recording EOs from the documents. These standardized tables were to be used for each SBA report and intended for cross-SBA integration of the EO needs. During the methodology development it became evident that, for the AQ EO needs and priorities, additional attributes beyond those given as guidance.

The metadata for each document included information about the source, the form and the content of the selected, publicly available documents.The metadata extraction process included the following steps: Once a relevant document was identified, it was assigned an ID number, a hard copy was printed and a table was attached to help the Analyst extract the needed information. The table included information about the document: the title, region and document type and AQH observation category (emission, SRR, ambient, health). It was also noted if the document contained "needs" for the AQH categories. If the document included measured EOs, the parameters were noted and any information about spatial/ temporal coverage and resolution, accuracy and latency was recorded. This documented information along with an online link to the document was stored on a wiki webpage devoted to each document. These document-specific pages were used to deposit both structured metadata and also loose annotations on each document. These metadata were contributed by several members of the AQH Analyst group. This open wiki approach allowed both the independent verification and also the evolutionary changes in this meta-analysis. The resulting online catalog of all data for this meta-analysis was created[2].

The metadata extracted from each document were also entered into a spreadsheet[3] for further analysis, which included filtering and aggregation of the records by region, pollutants, observation category, etc. . A separate spreadsheet was used to analyze

2. http://wiki.esipfed.org/index.php/GEO_User_Requirements_for_Air_Quality_Documents-CandidateDocs

3. http://wiki.esipfed.org/images/b/ba/20091018_GeoTaskDocParams-11.xls

the AQ monitoring station coverage data.

The documents identified in Section 2.3.1 were examined 3 to 5 times. The first scan focused on the general suitability of the document for consideration in this assessment as outlined above. During the second scan, detailed data extraction was performed and recorded into the document's metadata record. It yielded factual data regarding the observations (e.g. coverage, space and time resolution, geographic region, document type.. etc). The purpose of the third scan was to seek additional EO requirements that could only be inferred from the documents. The nature of the inference was also noted in the document's metadata record. Because the metadata extraction methodology evolved during the four month analysis period (June-September, 2009), additional document scans were performed iteratively to extract additional metadata for the evolving database.

2.3.3 Methodology for Determining EO Priorities for AQH

The adopted method for this analyisis uses three independent measures to prioritize EOs for AQH of the observation: (1) The health effect potency of the pollutant; (2) Spatial-temporal coverage; and (3) General utility of the observation. The overall priority is obtained by combining these three measures, weighed by subjective weight factors for each independent measure.

1. Pollutant health effect. This measure ranks the pollutants by their overall toxicity at ambient concentrations. The highest priority is assigned to those air pollutants that have been shown to have the most serious effects on human health. This prioritization is based on the scientific evidence obtained from the epidemiological studies world-wide. The specific pollutants used are those identified in the WHO Guidelines (WHO, 2005).

2. EO spatial-temporal coverage. This measure is independent of the pollutant and measures EOs by their ability to provide spatial and temporal characterization of air pollutants. The highest ranking is given to observations that improve the coverage most, i.e. fill in the spacial-temporal data gaps where these are most needed. This aspect of EO prioritization is aimed at reducing the uncertainty in estimating population exposure of the global population. The priority is given to EO regions where the gap between the current AQ monitoring density and a desired monitoring density is the largest, i.e. the populous developing regions of the world.

3. EO utility. This measure ranks observations by their general utility or re-usability for characterizing the air pollution system. For example, if the measured pollutant is toxic substance, the observation provides extensive coverage and it also well suited for emission estimation, then it is ranked higher than an observation for single use. An iterative emission-observation-exposure-modeling reconciliation system would rate highest by the EO utility criteria.

Combining these independent (orthogonal) measures of EOs is a challenge. The scale used for each of these independent measures is the ranking along the respective axes. This provides a homogeneous metric for the three independent measures. The overall priority is obtained by attaching a subjective weight factor to

each of the three measures and summing the weighted ranking. Observations that rank high by each measure recieve the highest overall ranking. Initially, the Analyst offered a set of simple weight factors: unity for each subjective weight. Subsequently, the Advisory group will be polled to suggest alternative weight factors for the three measures.

It is understood that EO prioritisation is an ill-defined problem. Developing an optimal EO prioritization is only possible if all the AQH processes, parameters and their respective spatio-temporal pattern are fully understood. Since such a full understanding is not on hand, the prioritisation has to follow an iterative approach: As new undestanding is gained, the prioritisation needs to be reassessed.

3 Air Quality and Health Sub-Area

The Health SBA aims to understand and quantify the environmental factors affecting human health and well-being. According to the GEO 10-Year Plan Implementation Plan (GEO, 2005a):

> *"Health issues with Earth observation needs include: airborne, marine, and water pollution; stratospheric ozone depletion; persistent organic pollutants; nutrition; and monitoring weather-related disease vectors. GEOSS will improve the flow of appropriate environmental data and health statistics to the health community promoting a focus on prevention and contributing to the continued improvements in human health worldwide."*

Air Quality and Health (AQH), the topic of this report, is a sub-area of the Health SBA. It examines the role of outdoor air quality for human health and well-being. This particular meta-analysis is to aid GEOSS achieving its long-term goal of facilitating the provision and flow of appropriate environmental data to the health community. The Health SBA is also addressed in two additional reports: Infectious Diseases and Aeroallergens.

3.1 Air Quality and Health Description

The framework used in this analysis is shown in the systems diagram of AQ management (Figure 1). Air pollution is caused primarily by ***Human Activities (HA)*** and through a feedback loop, it is also mitigated by societal actions that reduce the levels of air pollution. Figure 1 defines the system components and the scope of EOs for the AQH sub-area.

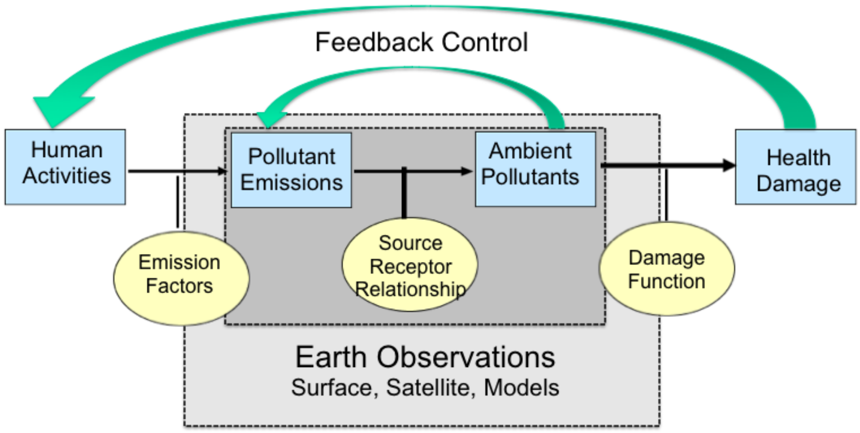

Figure 1. Framework for Categorizing Earth Observations for Air Quality and Health

In the industrial world, the overwhelming majority of air pollution ***Emissions*** originate from the combustion of energy-producing fossil fuels, coal, oil and natural gas. The magnitude of the emissions is determined by the ***Emission Factors (EF)*** associated with human activities. The emission-rates along with the ***Source-Receptor-Relationship (SRR*** atmospheric dispersion, chemical transformation and removal processes), determines the ***Ambient Pollutant (AP)*** concentrations. The overall global-scale ***Health Damage (HD)*** is the consequence of the ambient pollutant burden end exposure. Its magnitude is determined by the ***Damage Function (DF)*** and population density. The total global damage is? This generalized framework is applicable to all human-induced AQ problems, regardless of the sources of the human-induced emissions and the nature of the resulting AQ damage.

Figure 1 indicates that major elements of the AQ system are quantified through Earth Observations, i.e. measurements and suitably evaluated air quality models. In particular, the characterization of the ambient pollutant concentration and evaluating the SRR depends largely on EOs and the underlying atmospheric science (dark shading). Furthermore, EOs can improve emission estimates and forecasting. EO-based "top-down" emission measurements are gaining increasing applicability (Dabberdt and McHenry, 2004; NARSTO, 2005). The SRR is generally derived from AQ models that simulate the atmospheric processes and the models themselves are developed, calibrated and verified using EOs. Advanced AQ models are now assimilating EOs to improve their forecast performance (IGACO, 2004).

The above systems approach yielded progress on improving air quality in many parts of the world, particularly over NAWE. The emission reductions were motivated by scientific evidence of adverse impacts and the progress was achieved through the implementation of science-based policies and through advances in technology (Brooks et al., 2009).

The estimation of health impact based on research conducted in NAWE is only partially applicable to developing countries. While many similarities exist in the constituents of air pollution around the globe, the nature of air pollution in developing regions may be significantly different from those in NAWE. The human activities, the

emissions, ambient concentrations are all specific to particular regions. Major cities in Asia and Africa have many diffuse, difficult-to-control sources (e.g. open burning, low-quality indoor fuels, and uncontrolled small businesses and industries) (HEI, 2004). The transportation-related emissions and ambient concentrations near roadways are also region-specific. In many areas of the world, significant fraction of the ambient pollutants originate from agricultural biomass burning, forest or Savannah fires or dust storms. In forested regions of Africa, forest fires increase the risk of acute respiratory infections (UN, 2001). Unfortunately, the above variability of AQ in the developing world is very poorly characterized.

Consequently, health impact estimation for the developing regions is highly uncertain (HEI, 2004; Vliet and Kinney, 2008; Cohen, et. al., 2004). The uncertainties span all of the components of the AQ system: emissions, SRR, ambient concentrations and exposure damage

In spite of these uncertainties, the World Health Organization (WHO) ventures to estimate that urban air pollution contributes each year to approximately 800,000 deaths and 4.6 million lost life-years worldwide (WHO 2002). Particulate air pollution is consistently and independently related to the most serious effects, including lung cancer and other cardiopulmonary mortality. This amounts to about 0.8 million (1.2%) premature deaths and 6.4 million (0.5%) years of life lost. This burden occurs predominantly in developing countries; 65% in Asia alone. (Cohen, et.al., 2005)

3.2 Air Quality Sub-areas

Air Quality itself is a sub-area of the Health SBA. For this analysis, air quality is divided into three sub-areas of the AQ system that are relevant to the prioritization of AQ Earth observations: (1) Air pollutants damaging to health. (2) Observation coverage (3) Observation utility.

3.2.1 Air Pollutants Parameters

The first sub-area identifies air pollutants that are considered most harmful to human health. There is firm and accumulating scientific evidence that trace concentration of pollutant gases and particles in the ambient air affects human health (e.g. Cohen et. al., 2004). The health effects range from mild eye irritation to death. A key outcome of the air pollution health research is the identification of the key pollutants and their respective effects on human mortality and morbidity. The needs for this sub-area are determined from the available air pollution-health research.

3.2.2 Air Quality Observation Coverage

The second sub-area addresses observation coverage as part of the characterization of the AQ system. AQ characterization includes documenting the spatio-temporal distribution of the ambient air pollution. Most air quality observations for health are obtained from surface-based monitoring stations. The observation

coverage measures the certainty at which the pollutant concentrations can be estimated.

The observation needs for this sub-area are assessed based on the regional availability of AQ observations. Specifically, the need is measured by the gap between the current observation coverage in the developing regions and the coverage that exists over the most intensely monitored North America.

3.2.3 Air Quality Observation Utility

Th third sub-area is observation utility. Observations that have application in multiple segments of the AQ system have higher utility. EO utility is evaluated based on expert judgement.

3.3 Document Classification

Over a hundred documents were consulted for this meta analysis originated from different regions of the world. Given the strong regional variation of both air pollution and population in this report, the Analysts chose the following regions for analysis: Africa, Asia-Southeast, Asia-Non Southeast, Europe and N. America. Southeast Asia includes the fast-developing and populous countries of India, Indonesia, China and Japan. Australia and South America were omitted from this meta-analysis due insufficient document sample size. Documents prepared for international organizations and covering multiple regions are assigned the category ‘International’.

Table 2 shows the geographic origin of all documents analyzed, the documents used to identify the number of monitoring stations. The gray columns to the right indicate the number of total documents for each region and the number of station documents by region. The large number of consulted documents in Asia and Africa is due to the documents used primarily for the monitoring station analysis. On the other hand, the international reports represent mostly consensus reports.

Table 2 : Document Source by Region*

	References		Number of Documents	
Region	**All**	**Station**	**Total**	**Station**
Africa	*1,15,23,25,31,32,52,53,54,55,56, 57,58,64,67,68,69,70,109*	*52,53,54,55,56,57,58, 64,68,69,109*	**18**	**11**
Asia Non SE	*65,71,72,73,90,91*	*71,72,73,91*	**6**	**4**
Asia Southeast	*19,20,29,39,41,50,51,74,75,76,77, 78,79,80,81,82,83,84,86,87,88,89, 92,93,97,110*	*19,74,75,76,77,79,23,81, 82,83,84,86,87,89,92,110*	**25**	**16**
Europe	*3,4,6,9,35,37,60,61,62,63,94*	*94*	**11**	**1**

International	*2,10,11,13,14,16,17,18,21,33,34, 45,46,47,59,98,99,103,105,106,107*		**21**	
N. America	*7,8,12,22,26,27,28,36,38,40, 42,43,44,95,96,100,101,102,104*	*26*	**19**	**1**

* The italic numbers in each row represents the document ID used in Appendix B.2 Documents and References Consulted.

3.4 Uses and Users of EOs for Air Quality and Health

There are three general uses and corresponding user classes of EOs for AQH.

General Public. The general public is the broadest group of users of AQ observations. The Public may be interested in air quality forecasts for planning daily activities, alerts and action steps during air pollution events; and learning about the general causes and pattern of AQ in their neighborhood.

Air Quality Managers. They are responsible for the mainatance of healthy air quality by setting AQ standards, monitoring the air quality and if necessary, initiating control actions. AQ policy makers provide general guidance to the managers.

Scientists. They perform the research on atmospheric processes including emissions, transport, chemical transformation and removal processes on local, regional and global scales. They develop and evaluate chemical transport models that are used for forecasting, evolution of control strategies and policies.

The information needs of most users are addressed using derived data and information products rather than raw EOs (CDC, 2008). For instance, in providing EO to the public, multiple pollutant concentrations are combined into a derived Air Pollution Index. These information products can be derived from the raw observations using well-defined numerical or statistical procedures. Scientific users tend to require raw observations to derive the resulting products. For assessing EO priorities it was decided to focus on the needs and prioriterization of raw EOs.

4. Earth Observations for Air Quality and Health

This section contains the results from the analysis of the documents and the specific observation parameters/characteristics that the analysis revealed for each sub-area.

4.1 Earth Observations by Parameter

The relevant AQ parameters may be assessed from multiple perspectives:

- Observations identified as needed by best available Health Science
- Required by ambient AQ Standards and Guidelines
- Pollutant measured or estimated by current observing systems
- AQ Observations reported in the public documents

4.1.1. Air Pollutant by Severity of Health Effects

Particulate air pollution, specifically PM2.5, is consistently and independently related to the most serious health effects, including lung cancer and other cardiopulmonary mortality (Cohen, et.al., 2005). The WHO air quality guidelines (WHO 2005) also identify fine particles (PM2.5) as one of the most dangerous pollutants for human health. Of the gaseous pollutants sulfur dioxide and nitrogen dioxide were found to be causal factors in human health effects (HEI, 2004).

4.1.2 Air Pollutants required by Standards

The air quality parameters of highest significance to human health are encoded in the WHO Air Quality Guidelines (WHO, 2005). Table 3 identifies PM2.5, PM10, O3, NO2, and SO2 as a specific pollutants, the maximum allowable concentration, averaging time and the appropriate statistical measure. WHO recommends that these maximum values are not to be exceeded anywhere in order to significantly reduce the adverse health effects. The European Union directive (EC, 2008) follows the WHO 2005 Guidelines. In the U.S., Canada and other countries, the allowable levels of these pollutants are encoded in enforceable ambient air quality standards. While the specific threshold values and statistical measures may vary somewhat by country, the general level and form of these AQ standards are similar to the WHO Guidelines. For this report, WHO Guidelines are adopted as the document representing the EO needs for AQ parameters.

Table 3. WHO Guidelines for maximum allowable air pollutant concentrations.

Pollutant	Averaging time	AQG value
Particulate matter		
$PM_{2.5}$	1 year 24 hour (99th percentile)	10 μg/m^3 25 μg/m^3
PM_{10}	1 year 24 hour (99th percentile)	20 μg/m^3 50 μg/m^3
Ozone, O_3	8 hour, daily maximum	100 μg/m^3
Nitrogen dioxide, NO_2	1 year 1 hour	40 μg/m^3 200 μg/m^3
Sulfur dioxide, SO_2	24 hour 10 minute	20 μg/m^3 500 μg/m^3

4.1.3 Air Pollutants by Bibliometric Analysis

In order to assess the attention given to individual air pollutants, the documents were examined for particular AQ parameters. The rationale for this tabulation is that pollutants for which observations are more important would be reported more

frequently in the consulted documents. The resulting bibliometric analysis of the consulted documents is given in Table 4. For each pollutant, the italic numbers are the references consulted (Appendix B2). The far right column in Table 4 indicates the number of documents that measured a given pollutant. As indicated for Table 2, the large number of documents for Asia and Africa is due to the documents used primarily for the monitoring station analysis.

Table 4: Documents EO measurements by pollutant*

	Africa	Asia Non SE	Asia Southeast	Europe	International	N. America	Number of Docs
SO2	*32,52,53,56, 57,58,64,68, 69*	*65,73,90,91*	*19,39,50,51, 74,75,76,77, 78,79,80,81, 83,84,86,88, 89,92*	*4,6,60,61, 94*	*18*	*8,22,26,27, 28,43,95*	44
NO2	*32,52,53,56, 58,64,68*	*65,71,90*	*19,39,50,51, 74,75,76,77, 78,79,80,81, 84,86,88*	*4,6,60,61, 94*	*18*	*8,22,26,27, 28,43,95*	38
NOx	*32,58,69*	*73,91*	*19,39,75,83, 89,92*	*6,60,61,94*	*18*	*27*	17
CO	*15,32,52,58, 64,68,69*	*65,71,73,90, 91*	*19,39,50,74, 75,76,77,79, 80,81,83,84, 88,89,92*	*6,60,61,94*	*18*	*8,26,27,43, 95*	37
O3	*15,32,52,58, 64*	*71,73,90,91*	*19,39,74,75, 76,77,78,79, 80,81,83,84, 89*	*6,60,61,94*	*13,18*	*8,12,22,26, 27,28,43*	35
VOC	*15,32,52,58, 69*	*73,91*		*6,60,61,94*			11
PM10	*32,52,56,64*	*71,73,90,91*	*19,50,51,75, 76,77,78,79, 80,89,93*	*4,6,60,61, 94*	*13,17,18*	*8,22,26,27, 44*	32
PM2.5	*56*	*73,91*	*80*	*4,6,60,61, 94*	*14,17,18*	*8,12,26,27, 28,44*	18
Lead	*64*	*72*	*19,39,75,80, 83*	*37,94*		*26*	10
Aer. Carbon	*68*		*83*	*4*	*14*	*26*	5
TSP	*53,57*	*65*	*39,74,75,77, 80,81,82,83, 84,86,88,92, 93*				16

AOD				*61*		*26,44*	3
HNO3				*6*		*27*	2
POPs				*6,62,94*			3
HCHO						*43*	1
AQI				*61*			1
Weather		*91*	*84*			*12*	3

* The italic numbers in each row represents the document ID used in Appendix B.2 Documents and References Consulted.

Figure 2 shows the key results of Table 4. The six pollutants to the left (blue) are gaseous pollutants while the next six parameters (red, yellow) are different measures of particulate air pollution. The remaining parameters to the right (green, light blue) fall in the miscelleneous category. The most frequently reported pollutants were SO2 , NO2, CO, O3, and PM10. This is expected since each has been implicated in health effects and also identified in National Air Quality Standards and WHO AQ guideliness.

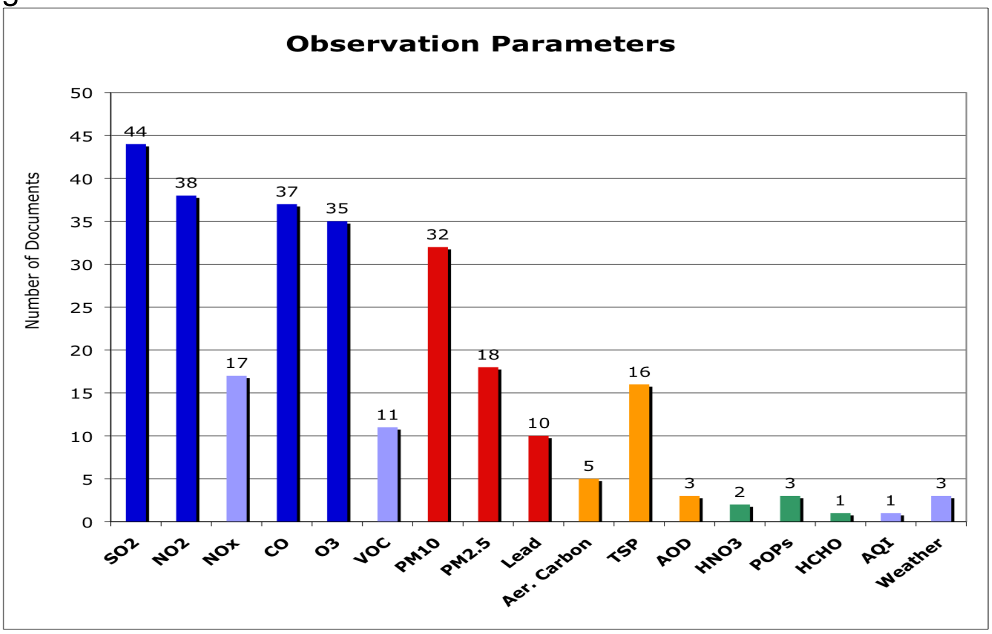

Figure 2: Bibliometric Frequency of Air Pollutants Observations.

Sulfur dioxide (SO_2) is the most frequently referred pollutant followed by ozone, NO_2, CO, PM_{10} and $PM_{2.5}$. PM_{10} is the mass concentration for aerosol particles below 10 micrometers, while $PM_{2.5}$ is the particle mass below 2.5 microns. Each of the discussed pollutants have been identified through epidemiological studies as causal factors in human morbidity or mortality. Lead (Pb), also a toxic substance is referred

less frequently, presumably since the main source of ambient Pb, i.e. Pb in automotive gasoline, is being phased out world-wide.

The top list of the six referenced pollutants: SO_2, NO_2, O_3, CO, PM_{10}, $PM_{2.5}$ constitute the short list of 'essential air quality variables'. These are analogous to the 'essential climate variables' identified in the companion report on EO priorities for Climate. The intense attention to this list can be explained by the fact that these pollutants are societally regulated by environmental laws in many countries of the world, i.e. the emissions and/or the ambient concentrations are subject to enforceable and mandatory standards.

Nitrogen oxides (NO_x=NO+NO_2) and Volatile Organic Compounds (VOCs) are both precursors of ozone, which is formed in the atmosphere through photochemical reactions of NO_x and VOCs. The observation of these compounds is necessary for understanding behavior and controlling the sources of tropospheric ozone. These constitute the second-tier of essential air quality variables.

The next three observed AQ parameters are Aerosol Optical Depth (AOD), Carbonaceous Aerosols and Total Suspended Particles (TSP). These are different measures of aerosols that are useful for the understanding of aerosol sources, transport, vertical aerosol burden or may serve as surrogates for PM_{10} or $PM_{2.5}$. Nitric Acid (HNO_3) is a reaction product of NOx and formaldehyde (HCHO) and is an indicator of natural organic emissions. Persistent Organic Pollutants (POPs) are long-lived toxic substances arising primarily from pesticide use. The air quality index (AQI) is a derived variable from the combination of the essential air quality variables. Weather parameters (temperature, humidity, precipitation, visibility) are observed along with the pollutants. There are numerous other gaseous and aerosol composition parameters that are measures for research or specialized applications. For the source-apportionment and for health effect research highly speciated aerosol measurements are used.

4.1.4 Air Pollutants by Monitoring Stations

This measure indicates the number of monitoring sites that are reported for each air pollutant (Table 5). Table 5 shows the number of monitoring stations over NAWE and the developing countries separately in order to indicate the difference.

Table 5. References and Number of stations for NAWE and Developing Countries

	References		**Number of Stations**	
	NAWE	**Dev_World**	**NAWE**	**Dev_World**
SO2	*94,26*	*52,53,56,57,58,64,68,69,73,91,19,74,75,76,77,79,23,81,83, 84,86,89,92,*	5634	3380
NO2	*94,26*	*52,53,56,58, 64,68,71,19,74,75,76,77,79,23,81,84,86*	6120	3483
NOx	*94*	*58,69,73,91,19,75,23,83,89,92*	5200	904
CO	*94,26*	*52,58,64,68,69,71,73,91,19,74,75,76,77,79,23,81,83,84,89,92*	4596	1976

O3	*94,26*	*52,58,64,71,73,91,19,7475,76,77,79,23,81,83,84,89*	5398	2672
VOC	*94*	*52,58,69,73,91,23*	1210	382
PM10	*94,26*	*52,56,64,71,73,91,19,75,76,77,79,23,89*	5653	1402
PM2.5	*94,26*	*56,73,91,23*	4100	101
TSP	*26*	*53,57,74,75,77,23,81,82,83,84,86,92*	111	3272
Pb	*94,26*	*64,72,19,75,23,83*	3731	612

* The italic numbers in each row represents the document ID used in Appendix B.2 Documents and References Consulted. Add population and per-capita #s

Figure 3 shows number of stations measuring pollutants for NAWE and developing world. Note that almost all PM2.5 monitoring occurs in NAWE. Also note that the developing world still conducts significant monitoring for TSP, while NAWE do not.

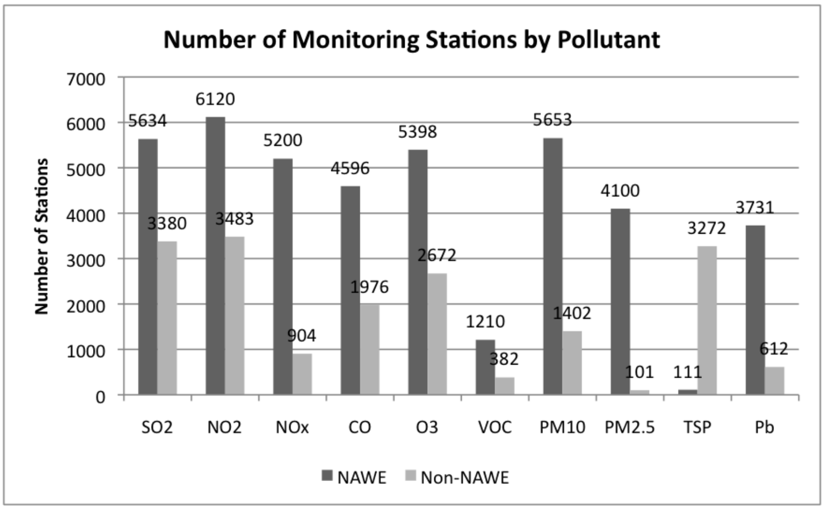

Figure 3. Monitorting by Parameter for developing and nam/europe (add # to columns and light/dark colors)

4.2 Earth Observations by Coverage

This section describes the results of the global ambient AQ monitoring coverage as compiled from the available public documents. The description includes the main sources used and comments on the regional characteristics. The number of sites are aggregated over the six global regions[4]. The specific documents used in this monitoring coverage analysis are listed in Table 6 along with the monitoring stations by region.

Table 6. References for Number of Stations and Number of Stations for each Region

Region	Reference	Number of Stations

4. South America and Australia are not covered due to the paucity of data and insufficient time for this report.

Africa	*52,53,54,55,56,57,58,64,68,69,109*	419
Asia, Southeast	*71,72,73,91*	3407
Asia, Non SE	*19,65,74,75,76,77,79,23,81,82,83,84,86,87,89,92,110*	191
Europe	*94*	3418
N. America	*26*	3904

* The italic numbers in each row represents the document ID used in Appendix B.2 Documents and References Consulted.

For North America (NAM) the Survey on AQ Monitoring by the Committee on Environmental and Natural Resources Research and the Air Quality Research Subcommittee (CENR, 2009) was used to estimate the number of stations for Canada, Mexico and the U.S. This recent survey also contained extensive information on other aspects on the status of the North American AQ monitoring, including measured parameters, lead agency, and year the monitoring began. For NAM, a total of 3904 monitoring sites were reported, mostly operated by environmental agencies in the US (3485), Canada (308) and Mexico (111).

The European Monitoring Exchange Network (EU, 2007) now reports the number of monitoring stations for each pollutant parameter for 33 countries in Europe including 27 EU member countries. The breakdown for each pollutant also classifies station type for each pollutant measured (i.e. Traffic, urban background, etc). All European countries except Russia were found from this source. For Europe, there are 3418 reported stations, operated mostly by the environmental agencies? (are stations mostly in W Eurpope) . Russia (681), Italy (549), France (521) and Germany (467) contributed 65% of the European Stations.

For Africa the Air Pollution Information Network for Africa (APINA, 2009) fact sheets for individual countries contained the information on the number of monitoring sites in the countries: South Africa, Mozambique, Zambia, Malawi, .Botswana and Zimbabwe.. For Egypt, the environmental ministry website contained detailed information on monitoring sites. For Tunisia, Morocco, Tanzania, the station data were obtained from environmental organization websites. For the remaining African countries, no monitoring information was found.The total number of reported/found stations is 419, virtually all in four countries: South Africa (266), Mozambique (53), Egypt (42), Botswana (17).

For the populous Southeast Asia, a catalog of monitoring station information was not found. However, Clean Air Initiative (CAI-Asia, 2009) website provided links to the websites of environmental ministries and departments that contained such information. A total of 3407 monitoring stations were identified in the 14 countries of SE Asia, stretching from India to Japan/Philippines. A surprisingly high number of the stations are reported for Japan (1910). China (559), India (290), and South Korea (271) are all further key contributors the AQ monitoring in SE Asia.

For the remaining, less populous Non-Southeast Asia (Asia NSE), the meager station count data was obtained form two sources. The stations count for Afghanistan, Iran, Jordan, Iraq was obtained from (CAI-Asia, 2009) or through Google searches. For countries of the former Soviet Union which include the Russian Federation and other Asian USSR countries, the ambient monitoring information was obtained from the reports of a WHO Workshop. (WHO, 2003).

Below are several comments and concerns regarding the monitoring station coverage data. The number of stations reported here are those extracted from the publicly available documents or other meta analyzes. An independent verification of these numbers was not possible, but the Analyst speculates that the given numbers are too high. Also, the majority of the monitoring systems reported for Africa and Asia were installed since about 2005.

A summary of the regional station coverage data is shown in Figure 4. For each region, the bar height depicts the number of monitoring sites per person. The highest station coverage is in NAWE, averaging respectively about 9 and 5 stations per million persons. On the other extreme, Africa and Asia NSE average about 0.5 stations per million persons. Asia SE has about 1 station for each million persons, but if one excludes the 2000 stations in Japan, the remainder of Asia SE is again at about 0.5 stations/million persons. This analysis provides quantification of the needs/ requirement for AQ monitoring over the developing regions, particularly in areas of high population density. In particular, it highlights the factor of 10-20 disparity in regional monitoring between the developed and developing regions.

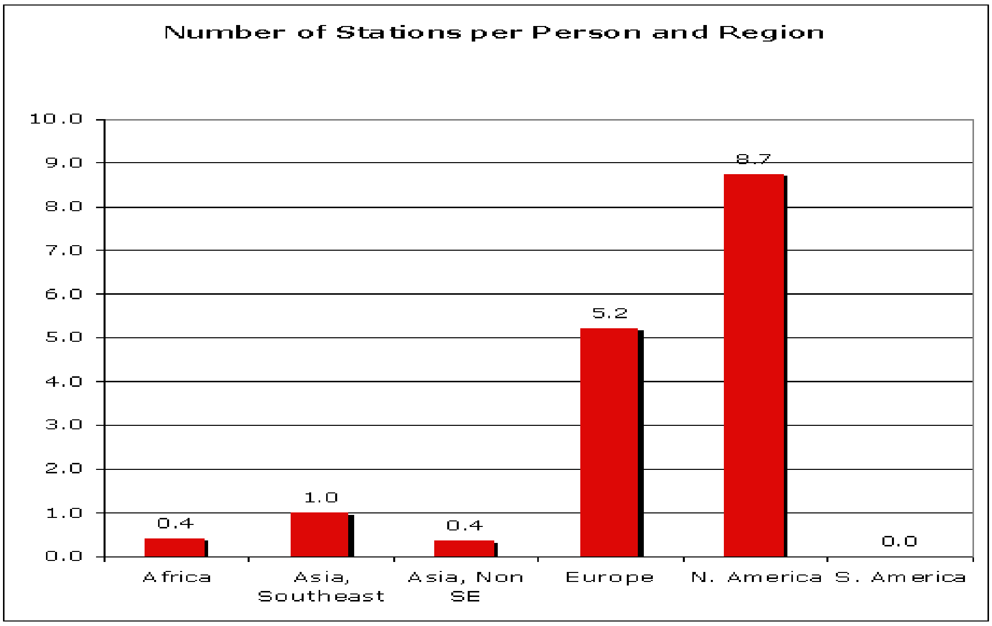

Figure 4: Number of stations/million person for each region

Monitoring AQ over the developing regions is necessary but not sufficient to satisfy the needs/of health officials, AQ managers and the general public. Having monitoring sites (announced or operated) by a national agency does not mean that monitoring data are publicly available. In fact, very little evidence is provided that the AQ

monitoring data from the developing countries are accessible to the global public health community. A review of the literature shows that only a small fraction of the potentially useful monitoring data is publicly accessible. A recent meta analysis by HEI (HEI, 2004) reinforces this poor data availability. The study shows that in developing countries of Asia there were 138 health studies conducted, 44 studies in China alone. In order to perform the health effect studies, air pollutant measurements were necessary along with the health indicators. Frequently, the AQ monitors were set up and operated for short periods of time. However, these monitoring data are not available for verification or reuse (Vliet and Kinney, 2007; UN, 2001).

Monitoring data for PM10/TSP area available for only 304 cities of the world. Of these, 268 (88%) are located in NAWE where 20% of the global population. The bulk of the global population (80%) has only has data for 36 cities (Cohen et. al., 2004). This indicates a disparity of a factor of 30 in the per person data availability between the developed and developing counties. The paucity of the accessible AQ data in the non- NAWE world reinforces the need for clearly separating AQ monitoring and data availability statistics.

4.2.1 Vertical Column and Profile Observations

Surface observations are necessary to estimate the population exposure to air pollutants. However, surface observations characterize only a small fraction, a thin horizontal slice of the AQ system. Although breathing zone monitoring is a rich data source, most pollutant mass resides beyond the reach of surface stations. Since virtually all the atmospheric processes are happening aloft, vertical column and profile observations are key to a complete characterization of the AQ system.

Column observations from remote sensors have the potential to cover broad spatial areas, in fact global coverage at relatively high spatial resolution. Collectively, the remote sensing techniques exists for measuring columns and/or profiles of aerosols (AOD), O3, CO, CO2, CH4, SO2, nitrogen oxides, CFCs, other pollutants, and atmospheric parameters such as temperature and H2O.

Remotely sensed observations can complement existing observational platforms and support the air quality assessment processes in multiple ways: (CENR --- Scheffe)

1. Providing direct observational evidence of regional and long range transport
2. Emission inventory improvements through inverse modeling,
3. Evaluation of Air Quality Models,
4. Tracking emissions trends (accountability), and
5. Complementing surface networks through filling of spatial gaps.

The spatial and temporal patterns derived from remote sensing (i.e., across days, weeks, or months) are well suited to determining, in an internally consistent manner, gradients in chronic exposure across large regions and among different countries. (Craig et al., 2008).

However, a better understanding of their spatial, temporal and measurement limitations is necessary to determine how these column observations can complement ground based networks and support AQH needs. (Hidy et. Al, 2010).

4.3 Earth Observations by Process Category

The content of the documents was classified by the AQH process that the document addressed (Table 7). Documents dealing with EOs for purposes of supporting emissions are labeled, or tagged, ‘Emission’. Similarly, documents dealing with SRR are tagged 'SRR' and those addressing observations on health and ambient air quality were tagged 'Health.'

The largest number of documents analyzed pertain to observations on the composition of the ambient air. Virtually, all these documents referred to data obtained through surface-based air quality monitoring stations. Given the rich bibliographic resource, it was possible to provide a bibliometric analyses of the frequency at which specific pollutants have been reported.

The observation categories are Emissions, Source-Receptor Relationship, Ambient Concentrations and Health, as defined in Section 3.1 Table 7 lists the documents consulted for each observation category. Table 8 lists those documents that contain explicit or implicit information about observation needs. At the bottom of both tables the total number of documents for each observation category is given.

Table 7: Documents by Observation Category and Region*

	References			
	Emission	**Source-Receptor**	**Ambient**	**Health**
Africa	*23*	*23*	*15,23,52,64,67,68,69,109*	
Asia Non SE			*65,71,72,73,90,91*	
Asia Southeast	*19*		*19,50,51,74,75,76,77,78,79,80,81,82,83,84,86,88,89,92,93,110*	*41,51*
Europe	*6*	*6*	*6,60,61,62,94*	
International			*13,14,18*	*13,14*
N. America	*43,44,95*	*43*	*8,22,26,27,28,43,44*	*8,22,28*
Number of Documents	**6**	**3**	**49**	**7**

* The italic numbers in each row represents the document ID used in Appendix B.2 Documents and References Consulted.

Table 8: Needs by Region Emission Transport Ambients Health*

	References			
	Emission	**Source-Receptor**	**Ambient**	**Health**
Africa		*15*	*1,25,31,52,53,56,57,70*	*25*
Asia Non SE			*72,73*	
Asia Southeast	*20*	*19,20,74,84,86,87, 88,89*	*20,29,39,41,50,74,82,86,87, 88,92,93*	*20,29,41,84*
Europe	*9,62,94*	*6,9,60,61,62,94*	*3,4,6,9,35,37,60,61,62,63*	*3,4,9,35*
International	*10,11,17,18,34,45,59*	*11,13,17,18,34,45,59*	*2,10,11,14,17,18,33, 34,45,59*	*2,10,11,14,33,34,59*
N. America	*7,26,36,38,40,95*	*7,26,38,40,42,95*	*7,8,12,26,36,38,40,42*	*7,8,12,26,36*
Number of Documents	**18**	**28**	**50**	**21**

* The italic numbers in each row represents the document ID used in Appendix B.2 Documents and References Consulted.

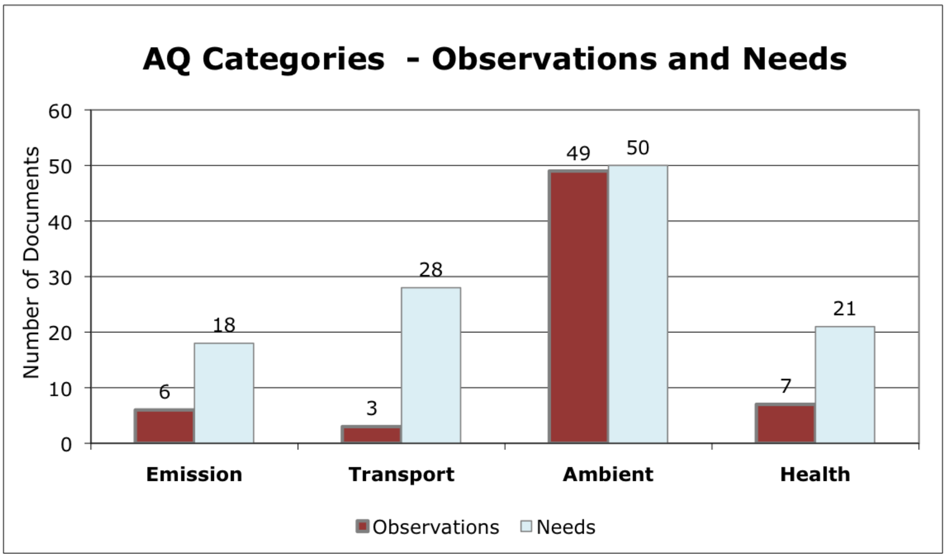

Figure 5: AQ Observation and Needs by Category

Figure 5 indicates that the majority of the consulted documents contain information on ambient observations or observation needs. Documents addressing emissions, source-receptor relationship and AQ-health were less selected. In all categories the documents expressing observation needs exceeded those that reported actual AQ observations.

5. Priority Earth Observations for Air Quality and Health

Priority observations for AQH are summarized in Table 9. The use of this standardized table was recommended for each SBA report. The observations categories in Column I indicate the AQ system components: Emissions, SRR, Ambient.

5.1 General Description

Observations for AQH are prioritized using three independent measures: (1) Air pollutant parameter; (2) Observation coverage and (3) Observation utility. The method used for the prioritization of pollutant parameters and spatial-temporal coverage is that of gap analysis. The gap is determined based on the difference between the desired state and the current state. The larger is the gap, the higher is the priority. The meta-analysis presented in section 4 is aimed to support the prioritization given below.

The first prioritization is by air pollution parameter. The desired list of monitored air pollutants is composed of those atmospheric constituents that represent the main causal factors in health effects. This list is taken from the WHO Guidelines (WHO, 2005). The current state of observations is obtained from the survey of global air pollutant monitoring, shown in Table 5 and Figure 3. Both the health research and the WHO Guidelines highlight PM2.5 as the main causal factor in health effects. On the other hand, the current observations are strongly skewed toward SO2 and other gaseous pollutants. The gap is in the relative attention and importance given to past monitoring priorities compared to the needs highlighted by more recent developments. Because of this gap, observations of PM2.5 are given the higher priority than any other air pollutant. The remaining Tier 1. pollutants in Table 9 are those listed in the WHO Guidelines.

The second prioritization is by observation coverage. The desired state of observation coverage is hard to quantify. However, the currents state of AQ monitoring over North America offers a reference for comparison with other less monitored regions. Figure 4 and Table 6 show that monitoring in N. America is about 9 stations per million persons compared to about 0.5 stations per million persons for the developing areas. The gap can be measured by the difference between the N. America and the developing regions. In fact, the monitoring density in N. America is about 20 times higher than that in the developing world. Based on the above criteria, in Table 9, the highest priority is given for the monitoring coverage over Africa and Asia.

The third prioritization is by observation utility. Observations that can be used to characterizefor multiple components of the air pollution system are given higher priority. Column concentration measurements, when properly combined with surface observations can contribute to ambient concentration measurements for areas that are not covered with surface monitors. Column concentration measurements can also be used to estimate pollutant emissions. In the presence of surface-based and

column measurements, the column observation may help with crude estimation of pollutant elevation. In Table 9, column measurements of the Tier 1 pollutants are listed as Tier 2 priority observations since they contribute to multiple aspects of air pollutant characterization.

In summary, this meta-analysis indicates that (1) the per-capita AQ monitoring in the developing regions of the world is 10-20 times lower than in the developed NAWE; (2) The monitoring of PM2.5, the best available indicator of health-related effects is virtually un-monitored with surface networks in the developing world; (3) The existing monitoring data from developing regions is less publicly accessible to the broader health community. Consequently, there is a need for (1) Significantly extended AQ monitoring in the developing world, particularly in the large, densely populated cities. (2) More intense monitoring of PM2.5 concentrations; (3) Improving the accessibility to AQ monitoring data by the broader communities in science, AQ management and the general public.

5.2 Priority Observations

Table 9. Priority Observations

GEO Task US-09-01a: Priority Earth Observations for Air Quality and Health SBA								
			Aggregated Characteristics of Priority Observation Parameters					
Observation Category	**Parameter**	**Spatial Priority**	**Spatial Resolution**	**Temporal Resolution**	**Accuracy**	**Latency**	**Other**
Tier 1							
Ambient	PM2.5	Africa, Asia	1 km city 10 km rural	1-hr	10-20%	Obs:1hr For Record: 1-3 days	
Ambient	SO2	Africa, Asia	1 km city 10 km rural	1-hr	10-20%	1-3 hours	
Ambient	NO2	Africa, Asia	1 km city 10 km rural	1-hr	10-20%	1-3 hours	
Ambient	O3	Africa, Asia	1 km city 10 km rural	1-hr	10-20%	1-3 hours	
Ambient	PM10	Africa, Asia	1 km city 10 km rural	1-hr	10-20%	1-3 hours	
Tier 2							
Ambient, Emissions, SRR	Column PM2.5	Global	1-10 km	1-hr	20%	1-3 hours	

Ambient, Emissions, SRR	Column SO2	Global	1-10 km	1-hr	20%	1-3 hours	
Ambient, Emissions, SRR	Column NO2	Global	1-10 km	1-hr	20%	1-3 hours	
Ambient, Emissions, SRR	Column O3	Global	1-10 km	1-hr	20%	1-3 hours	
Ambient	PM10	Africa, Asia	1-10 km	1-hr	10-20%	1-3 hours	
Ambient, Emissions, SRR	PM2.5 Species	Africa, Asia, Europe	1-10 km	1-hr to 1-day	10-20%	1-3 weeks	
Tier 3							
Exposure	Population	Asia, Africa	1 km city 10 km rural	5 years	20%		

6. Additional Findings

****** DRAFT ********

AQH is closely linked to other SBAs. On the causal side, the most significant connection is with the **Energy** SBA, since the overwhelming majority of anthropogenic air pollutants are caused by fossil fuel combustion. Forest fires and dust storms are major causes of air pollution events with extreme concentration of smoke and dust particles and ozone precursors, which links AQH to the **Disasters** SBA. **Weather,** in particular atmospheric ventilation is also a significant factor in the dispersion of air pollutants.

In addition to the effects on human health, air quality has impacts in other SBAs. Air pollutants, especially aerosols, perturb the Earth's radiative balance i.e. the link to Climate, but the magnitude and even the direction of the perturbation, i.e. heating or cooling, is uncertain. In fact, the main uncertainty in climate impact assessment is due to the uncertainty of radiative forcing from natural and anthropogenic aerosols. Deposition of acidic air pollutants contributes to the acidification terrestrial and aquatic **Ecosystems** and also a major source of terrestial and aquatic nutrients**.** Ambient ozone is known to produce damage to **Agricultural** plant growth.

7. Analysts Comments and Recommendations

DRAFT: This section is for the Analysts to provide their perspectives on the SBA, documents, set of observation priorities, etc. This section can be a bit more subjective than the other sections. This section might include perspectives on the US-09-01a process and suggestions for improvement.

****** DRAFT ********

7.1 Process and Methodology

This section contains the Analyst's perspectives on the overall US-09-01a process as well as perspectives on the analytic methods used. The section can certainly provide suggestions on how to do the process and analysis better in the future.

* Guidance and inter-SBA harmonization by the GEO Task Leader was helpful
* Way too short time.
* How and for what the meta-analysis will be used

7.2 Challenges

This section contains the Analyst's perspectives on key challenges faced in this activity, actions taken to address the challenges, and suggestions how to address, prevent, or overcome the challenges in the future.

* Prioritization methodology is not conceptually and practically difficult
* Sheer volume of diverse material is overhelming
* Engagement of AG, others was limited, too short time to discuss both method and output

7.3 Recommendations

This section contains the Analyst's recommendations to UIC how to improve the US-09-01a activity.

* Make process more open, process transparent, accessible, periodic
* Include broader community, encourage/facilitate more participation
* Encourage/facilitate dialog with users of Prioritization (UIC, others?)

NEEDS

Ideally, the EO requirements for AQH sub-areas would be extracted through a meta-analysis of existing public documents. However, very few public documents made explicit statements to specific EO parameters, spatial and temporal coverage, resolution or accuracy. Most documents refer to EO needs in general terms, e.g. need more monitoring stations, better emission inventories or the incorporation of

satellites and models. In other cases, scientific research groups listed their EO needs so widely that it included virtually all EOs. For this reason, the focus of this analysis was on the extraction of EOs that are currently being used. The “needs” are then determined from the gap between currently available EOs and a desired set of EOs. This approach was then used to evaluate and to recommend EO priorities, based on objective gap analysis and subjective weights attached to the different aspects of EOs.

This SBA is very different from other GEO SBAs that focus the natural Earth System as perturbed human actions. The full characterization of Biodiversity, Climate, Disasters, Ecosystems, Water, Weather or other SBAs requires a broad range of Earth observations, particularly for the detection and quantification of the human impact.

Appendix A: Acronyms

Abbreviation	Full Name
AG	Advisory Group
AIP	GEOSS Architecture Implementation Pilot
AOD	Aerosol Optical Depth
AQ	Air Quality
AQ CoP	Air Quality Community of Practice
AQH	Air Quality and Health
AQI	Air Quality Index
CAPITA	Center for Air Pollution Impact and Trend Analysis
CASAC	Clean Air Scientific Advisory Committee
CDC	Center for Disease Control
CO	Carbon Monoxide
EO	Earth Observation
EPA	Environmental Protection Agency
ERG	Eastern Research Group
ESA	European Space Agency
ESIP	Earth Science Information Partners
GCI	GEOSS Common Infrastructure
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
HCHO	Formaldehyde
HEI	Health Effects Institute
IGAC	International Global Atmospheric Chemistry
NAS	National Academy of Science
NASA	National Aeronautics and Space Administration
NAWE	North America and Western Europe
NH3	Ammonia
NO2	Nitrogen Dioxide
NOx	Nitrogen Oxides

O3	Ozone
PM	Particulate Matter
PM 10	PM less than 10 um in diameter
PM 2.5	PM less than 2.5 um in diameter
POPs	Persistant Organic Pollutants
SBA	Societal Benefit Area
SO2	Sulfur Dioxide
SRR	Source-Receptor Relationship
TSP	Total Suspended Particulates, PM of any size
UIC	User Interface Committee
VOC	Volatile Organic Compounds
WHO	World Health Institute
WMO	World Meteorological Institute

Appendix B: Bibliography and References

This section can list the documents and references in one list. Or, if preferred, this section can split the documents and references according to those "cited" and those "consulted."

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Extra Report Material